MOTOROLA

November 3, 2003

Mr. Edmond Thomas
Chief, Office of Engineering and Technology
Federal Communications Commission
445 12th Street S.W.
Washington, DC 20054

Mr. John Muleta
Chief, Wireless Telecommunications Bureau
Federal Communications Commission
445 12th Street S.W.
Washington, DC 20054

In re: WT Docket No. 02-55

Dear Messrs. Thomas and Muleta,

This letter is submitted in reference to the above captioned proceeding in response to requests from Commission staff. The staff has requested specific information on the embedded base of radio products in the 800 MHz band and the ability of currently deployed products to be reconfigured to operate in accordance with a new band plan. Commission staff has also requested information on a test methodology to readily determine the type and source of interference. Motorola appreciates the opportunity to provide the Commission with information useful in its deliberations in this proceeding.

I. Radio Equipment Issues

The Commission staff has requested information on the embedded base of radio products in the 800 MHz band and the ability of currently deployed products to be reprogrammed to operate in accordance with the 800 MHz plan proposed by the Consensus parties.

The specific details of any new band plan, and the manner and timing of its implementation, will impact the number of radios that need to be replaced rather than reprogrammed. Because the final details of any plan under consideration have not yet been determined, particularly in such areas as along the United States borders with Canada and Mexico, it is therefore not possible to respond definitively to some of the equipment impact issues poised by the Commission staff. However, Motorola is responding as completely and accurately as possible and would be pleased to provide additional information as necessary or as details become available.

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Table 1 provides information on Motorola radios sold over the past 10 years including whether the radio receiver meets the TIA 102 or 603 Class A or B specification for intermodulation performance, whether the model is still in production or, if not, its end of production date, and whether Motorola considers it feasible to reprogram[1] the radio if the Consensus plan currently on file with the Commission is implemented. Whether the radio can be reprogrammed or must be replaced is an estimate based on the Consensus plan channel arrangement for the non-border areas of the continental United States and assumptions about final FCC rules. The actual impact may vary depending on final details of the plan and, in particular, the final resolution of plans in the border areas.

The Commission staff has requested information specifically regarding equipment for the public safety market. While the features and functions of certain radio models make them more desirable for public safety users, public safety users are free to purchase any model radio. Accordingly, the information in Table 1, and the answers to the Commission staff questions is provided for Motorola radios that operate in the 800 MHz band, regardless of whether they have functions targeted specifically for public safety.

TABLE 1

Radio Model	IM Spec	RX Class Spec	Current Production or End of Production Date	Reprogram, Retune or Replace	821-824/ 866-869 Operable?
Voice/Primarily Voice					
Portables					
Astro Saber	-74dB	A	2Q2003	Reprogram	Yes
HT 1000 Con	-70dB	A	Current	Replace	Yes
LTS 2000	-65dB	B	Current	Replace	Yes
MT 1500	-70dB	A	New Prod-12/03	Reprogram	Yes
MTS 2000	-70dB	A	Current	Reprogram	Yes
MTX 8000	-70dB	A	Current	Retune	MA Note 1 Ch. Only
MTX 8250	-70dB	A	Current	Retune	No Note 2
MTX 850	-70dB	A	Current	Retune	No
XTS 5000	-75dB	A	Current	Reprogram	Yes
XTS 3000	-74dB	A	Current	Reprogram	Yes
XTS 2500	-70dB	A	Current	Reprogram	Yes
XTS 1500	-70dB	A	New Prod-12/03	Reprogram	Yes

[1] Radios operating in the NPSPAC channels will require new operating software and will be required to be "reprogrammed" or replaced. Radios not operating in the NPSPAC channels may need to be "retuned" or have their codeplug information modified to change the conventional and / or control channel information.

Radio Model	IM Spec	RX Class Spec	Current Production or End of Production Date	Reprogram, Retune or Replace	821-824/ 866-869 Operable?
GTX Port	-65dB	**B**	2001	Retune	No Note 2
Visar 800	-70dB	**A**	1999	Retune	no
Saber SI	-72dB	**A**	1994	Replace	Yes
MTX820	-60dB	**B**	1993	Retune	No
STX	-60dB	**B**	1991	Replace	Yes
STX Gemini Plus	-60dB	**B**	1991	Replace	Yes
Mobiles					
Astro Spectra	-80dB	**A**	Current	Reprogram	Yes
GTX Mobile	-65dB	**B**	Current	Retune	No
LCS 2000	-65dB	**B**	Current	Replace	Yes
MCS 2000	-75dB	**A**	Current	Reprogram	Yes
Spectra	-80dB	**A**	1999	Note 3	Yes
XTL 5000	-80dB	**A**	Current	Reprogram	Yes
MaxTrac	-68dB	**B**	2000	Replace	Yes
Spectra E	-80dB	**A**	1999	Note 3	Yes
Syntor X	-80dB	**A**	1991	Replace	Yes
Syntor X 9000	-80dB	**A**	1991	Replace	Yes
Data Devices					
Portables					
PRM 240	-60dB	**B**	Current	Reprogram	Yes
PRM 660	-60dB	**B**	Current	Reprogram	Yes
Mobiles					
VRM 850	-75dB	**A**	Current	Reprogram	Yes
VRM 650	-75dB	**A**	Current	Reprogram	Yes
VRM 660	-60dB	**B**	Current	Reprogram	Yes

Note 1 - In the 821-824/866-869 MHz band the MTX 8000 only operates on the 25 kHz wide Mutual Aid channels. Because the radio also currently operates in the 806-809/851-854 MHz band proposed as the new NPSPAC band, this radio can be retuned to continue to support 25 kHz Mutual Aid channels in the proposed band.

Note 2 – Some versions of this radio are capable of operating in the NPSPAC band. Such units would require reprogramming rather than retuning.

Note 3 – Motorola believes that these radios will require replacement. However, we are continuing to investigate to determine whether reprogramming would be feasible.

II. Equipment Performance

Questions one and two relate to the performance of currently deployed equipment. Responses are below.

1) What percentage of 800 MHz portable/mobile equipment (of all manufacturers), currently used by public safety agencies, do you believe meets:
(a) TIA Class A standards for the receiver section of the equipment?
(b) TIA Class B standards for the receiver section of the equipment?
(c) Neither standard

For the purposes of this question, Motorola is of the understanding that the FCC is primarily interested in the Class A or Class B intermodulation performance (IM) specifications in TIA-102 (narrowband digital) or TIA-603 (analog). The Class A and Class B receiver IM performance guidelines are:

TIA-102 Intermodulation Rejection Class A spec: Mobile 75 dB, Portable 70 dB
TIA-603 Intermodulation Rejection Class A spec: Mobile 75 dB, Portable 70 dB

TIA-102 Intermodulation Rejection Class B spec: Mobile 70 dB, Portable 50 dB
TIA-603 Intermodulation Rejection Class B spec: Mobile 70 dB, Portable 50 dB

Because of the durability of and resale market for equipment produced for the public safety community, it is extremely difficult, if not impossible to accurately determine which products are in current use or what percentage of the total embedded base a certain model of radio represents. Motorola is providing information for equipment sold over the last 10 years although the actual replacement cycle for products, generally in the 7-10 year range, will vary from licensee to licensee and may be either less than or greater than average.

Table 2 below provides information on the approximate percentage of Motorola radios sold over the last 10 years that are either Class A or Class B products based on their IM performance. Motorola does not have sufficient information on the performance or sales of products from other manufacturers to include them in this analysis.

TABLE 2 – 10-year Shipments by IM Class

Summary Answers	Class A	Class B
Overall	74%	26%
Portables	82%	17%
Mobiles	60%	40%

2) What percentage of your current production of 800 MHz portable/mobile equipment designed for the public safety market meets:
(a) TIA Class A standards for the receiver section of the equipment?
(b) TIA Class B standards for the receiver section of the equipment?
(c) Neither standard

While the features and functions of certain radio models make them more desirable for public safety users, public safety users may also purchase radios not intended specifically for the public safety market. Accordingly, the information in Table 1 describes the capability of the current shipping radios and some newly announced products that are about to ship. Based on 2003 year-to-date sales figures, the percentage of currently shipping radios in each category is shown in Table 3.

Table 3 – 2003 YTD Shipments by IM Class

	Class A	Class B
Portables	93%	7%
Mobiles	85%	15%

III. Rebanding Impact on Equipment

Question three concerns the equipment changes necessary to accomplish a rebanding of the 800 MHz band as proposed by the Consensus Parties. Prior to responding to question 3, some background on equipment operation is useful.

In its May 6, 2002 comments in this proceeding, Motorola estimated that approximately 30 to 40 percent of the 800 MHz mobiles/portable would need to be replaced under the rebanding proposed by Nextel in its original white paper and under the rebanding proposal submitted by NAM/MRFAC.[2] As described in that filing, factors that would require a radio to be replaced rather than reprogrammed include:

- *Memory capacity limitations*: In cases where the new software memory requirements exceed the memory capacity of a mobile or portable unit, a memory upgrade would be required to support reprogramming. Motorola believes that some of the NPSPAC compatible subscribers will fall into this situation because of significant differences in the existing and new channel lookup tables and algorithms.

[2] Motorola Comments, WT Docket No. 02-55, May 6, 2002, at 21-26.

- *Lack of availability of software development tools*: Software development tools and supporting test diagnostic tools may no longer be readily available for some older subscriber units that are no longer supported. Rebuilding the software development lab to support these older products will, in some cases, be cost prohibitive due to component obsolescence/unavailability.

- *Obsolescence of older subscriber units and retuning/reprogramming components*: Some retuning/reprogramming components and software code, especially on older subscriber units, may not be available or would be cost prohibitive.

- *Complexities arising from system coordination of software releases*: In some cases, coordination of some software releases for reprogrammed subscribers will trigger further retuning and reprogramming requirements to ensure compatibility with the infrastructure equipment. The retuning upgrade may rely on software versions and hardware configurations that are not in the users' original fielded system.

It is also helpful to understand the basic operation of a radio network to understand when it is necessary for radios to be replaced, whether the radio needs to be brought in from the field to be modified, or whether the radio can be adapted to the new plan via the control channel without physically touching the radio.

The Control Channel

Motorola trunked systems employ a control channel to control the behavior of radios on the system. The control channel sends channel number information to individual radios. Based on this channel number, calculations are performed in the radio software that enable the radio to select the channel center frequency and the appropriate transmitter deviation. The impact of rebanding or otherwise retuning the radio will depend on the specific circumstances for a given system. A general description is provided below:

A. <u>Retuning</u>

For the most part, a Public Safety or Private radio customer's 800 MHz radio currently operating <u>only</u> in the 806-821/851-866 MHz non-NPSPAC portion of the band can be retuned to operate in the 809-821/854-866 MHz non-NPSPAC portion of the new band plan. Within this band segment, radios on conventional systems that operate on different channels and on any Motorola trunked systems which operate on different control channels after rebanding will need to be physically "retuned" to the new channels through software adjustments. In addition, all Public Safety radios operating on conventional NPSPAC Mutual Aid channels will need to be physically "retuned" to the new channels through software adjustments. In-house or external service personnel authorized by the licensee would physically “touch” each radio to make these changes, i.e., the licensee must temporarily take the radio out of service for retuning. Conventional radios would have all operating channels retuned whereas trunked radios would have the control channels retuned.

Radios operating in 806-821 MHz solely on Motorola trunked systems that maintain the same control channels before and after rebanding do not need to be taken out of service for retuning, so long as the technical parameters and overall channel plan centers remain unchanged. Traffic channel selection is made dynamically based on the 806-821 MHz channel assignment algorithms inherent in the radio’s operating system software, control channel information programmed into the radios, the control channels programmed into the trunked system controller, and information sent dynamically from the controller over the control channels that tells the radio which traffic channel to select for a conversation. Here, the new operating channels are retuned into the controller rather than each radio. There is no need to retune the mobile or portable since the control channels have not changed.

Existing 806-821 MHz radios are capable of operating in the proposed new NPSPAC band. However, they would operate in accordance with the current 806-821 MHz specifications rather than specifications for operations in the NPSPAC band. If these radios need to meet the certification rules of the new band structure they may need to be ‘touched’ at least once or replaced.

In all cases, infrastructure base stations would need to be retuned and trunking controllers reprogrammed at a minimum if any of the system’s channels change. Depending on the new frequencies, supporting equipment such as duplexers, cavity filters, etc. may need to be adjusted or changed. Consoles may also need to be reprogrammed.

B. Reprogramming

Relocating current NPSPAC systems from the 821-824/866-869 MHz to the 806-809/851-854 MHz band as proposed in the Consensus Parties’ Plan requires product development. Motorola would need to develop new operating software and the new software must be fully tested to ensure there is no unintentional impact on other radio features before the new software can be reprogrammed into any NPSPAC radio that is to be rebanded. This development effort is needed because the new channel assignment algorithms inherent in the radio operating system software of each model radio must be added to implement rebanding.

For trunked systems, the channel assignment algorithm identifies the specific operating frequency associated with the designated channel number instruction sent to the radio from the controller. In addition to identifying the specific frequency, the operating software associates other technical parameters with certain channels. This association of technical parameters applies to all NPSPAC systems, both trunked and conventional. For example, with exception of the five mutual aid channels, operation on the NPSPAC channels requires that the transmitter deviation be reduced to 4 kHz. Receivers also need to track this reduced deviation to ensure that sufficient audio is recovered. Information inherent in the operating software instructs the transmitter and receiver sections of the mobile or portable radio to adjust the deviation parameters, based on the channel of operation. The operating software for the NPSPAC band also instructs the radios to operate on channel centers located every 12.5 kHz, rather than every 25 kHz as radios do today for the 806-821 MHz channel plan.

The software development required to support rebanding of Public Safety systems with NPSPAC channels is significant. Motorola has multiple models of radios already fielded in the 821-824/866-869 MHz band. Only some of these models have sufficient memory to accept new additional operating system software. Each of these models would need individual software development and testing effort. As addressed in section C below, remaining models would need to be replaced rather than reprogrammed.

C. Replacement Radios

Some models of NPSPAC radios have insufficient memory space to accept the new additional software. Also, for some older radios that may still be in service, the software development tools used to design the operating software as well as appropriate testing equipment and labs are no longer available. It would be prohibitively expensive to update these radios and more cost effective to replace them. Table 1 indicates which model radios Motorola believes will need to be replaced. Over 40% of the Motorola radios shipped with NPSPAC channels since the late 1980's potentially fall into the replacement category. However, given the age of some radios, we estimate that 30% of the Motorola NPSPAC radios still in use could fall into this category. [3] The actual number of radios in this category that are actually in use is somewhat uncertain because of varying equipment replacement cycles and a more accurate estimate would require an actual survey of all public safety systems.

D. Mutual Aid Complexities

Agencies who have the channels of neighboring systems programmed in for mutual aid purposes or who share channels with other agencies will also need to retune and/or reprogram the neighboring system channels. The timing of such retuning/reprogramming will depend on the rebanding implementation, the mutual aid agreements among the neighboring agencies or jurisdictions, whether the agency or jurisdiction is adjacent to a different rebanding region, and the agencies' operational

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[3] The reduction to 30% is based on an average 7 year life cycle for mobile and portable radios. However, we note that some licensees often keep radios in service longer than 7 years.

requirements. To prevent any temporary lapses in mutual aid compatibility may require the capability to operate under multiple bandplans pending completion of rebanding in an area. Depending on the timing of moving systems with which they have operational agreements some systems may need to be reconfigured multiple times. Agencies may have to make decisions whether to replace a greater number of radios or to forgo full interoperability during rebanding.

Band Plan Assumptions in Rebanding

In order to estimate the impact of rebanding on equipment in the 800 MHz band it's necessary to make certain assumptions about the final channel plan that will be implemented. The current FCC rules define all of the channel centers in the entire 806-824/851-869 MHz band. The channel center plan defined below is assumed to be the channel center plan that would be contained in revised FCC rules.

Motorola also assumes that the technical rules, specifically the tighter frequency stability and emission mask requirements, for the current NPSPAC 821-824 MHz sub band would be translated down to the new NPSPAC 806-809 MHz sub band. Motorola assumes that, in order to support NPSPAC operation in the 806-809 MHz sub band, the FCC will change the emission mask from a G mask to an H mask and will tighten the frequency tolerance from 1.5 ppm to 1.0 ppm for base stations and will tighten the frequency tolerance from 2.5 ppm to 1.5 ppm for portables and mobiles. This will be required if the current NPSPAC band frequency coordination is to be translated directly down 15 MHz to the proposed new NPSPAC band..

The channel center plan assumed by Motorola does not take into account channel use in the border areas with Canada and Mexico. Sharing arrangements in the border areas will likely result in channel arrangements different from non-border areas, with the possibility of mixing channels on 12.5 kHz centers with 25 kHz centers. Interleaving of 12.5 kHz and 25 kHz channel centers is not currently supported by non-Project 25 Motorola trunked systems. This would be a major impact to the new software development if the interleaved channel bandwidth arrangement is required. It is not clear to Motorola at this time how border area use will be resolved, and the resolution of those areas will impact implementation and transition to a new band plan. Until greater detail for these areas is provided, it is not possible to judge the impact on radio equipment.

The assumed channel center plan, for the NON-border areas, is shown in Table 4.

TABLE 4 – Channel plan in non-border areas

Base Frequency (MHz)	Type of Channel	Quantity of Channels
851.0125	Mutual Aid Calling Channel	1
851.0375 to 851.4875	Channels on 12.5 kHz centers; H mask	37
851.5125	Mutual Aid TAC channel # 1	1
851.5375 to 851.9875	Channels on 12.5 kHz centers; H mask	37
852.0125	Mutual Aid TAC channel #2	1
852.0375 to 852.4875	Channels on 12.5 kHz centers; H mask	37
852.5125	Mutual Aid TAC channel #3	1
852.5375 to 852.9875	Channels on 12.5 kHz centers; H mask	37
853.0125	Mutual Aid TAC channel #4	1
853.0375 to 853.9875	Channels on 12.5 kHz centers; H mask	77
	sub-total	230
854.0125 to 868.9875	Channels on 25 kHz centers; G mask	600
	TOTAL	830

3) Were the current band plan proposed by the Consensus Parties implemented:
(a) What percentage of Motorola public safety portable/mobile units could be retuned if an affordable hardware modification were made?

Motorola does not anticipate that hardware enhancements for any of the radios will be cost effective or practical as part of a reprogramming effort. For radios listed as reprogrammable in Table 1 the reprogramming will not require a hardware upgrade. Radios listed as requiring replacement cannot be reprogrammed to the new NPSPAC frequency plan because their firmware, hardware, and/or the radio service software will not allow the reprogramming. In most cases, production of these radios has either been discontinued, or it would not be cost effective to develop and install the hardware changes necessary for rebanding. As stated previously, Table 1 provides information on all Motorola radios sold primarily for use by public safety agencies in the 800 MHz band over the past 10 years. Most of the current products that cannot be reprogrammed are generally not specifically intended for the public safety market, however some public safety agencies may still purchase these products..

(b) What percentage of Motorola public safety portable/mobile radios could be retuned provided a software change (other than the software instruction necessary to add or delete a channel) were made?

(c) What percentage of Motorola public safety mobile/portable radios could be retuned without a software change, but with a need to touch the radio?

(d) What percentage of Motorola public safety mobile/portable radios could be retuned remotely without the need to touch the radio?

Questions b, c, and d are highly dependent on the specific implementation of a public safety system and the exact details of the new channels that would be used for each system. Without the final details of a rebanding plan and an audit of individual public safety systems Motorola does not have sufficient information to provide an estimate. However, all systems that use NPSPAC channels, including Mutual Aid channels, or which will change the control channel(s) will have to be touched by a technician. As addressed previously, some radios may need to be touched more than once. Any system that uses NPSPAC channels will either have new software developed and implemented, or will have to be replaced. As stated previously, over 40% of the Motorola radios shipped with NPSPAC channels since the late 1980's potentially fall into the replacement category. However, given the age of some of radios, Motorola estimates that 30% of the Motorola NPSPAC radios still in use could fall into this category. Based on this estimate, approximately 70% of radios that use NPSPAC channels could be reprogrammed with new software.

If old currently deployed radios are required to meet new certification requirements limiting their ability to operate in certain portions of the 800 MHz band, all radios may need to be touched at least once.

(e) For each radio in categories (a) to (d) above, which can be retuned, what would be the approximate cost of retuning?

The cost per radio for reprogramming or retuning will depend on a variety of factors, such as whether the public safety entity has technicians in-house that can perform the reprogramming or whether the work needs to be done off site or the numbers of units to be programmed (a larger number will provide an economy of scale for the work). In their December 24, 2002 filing, the Consensus Parties estimated a cost of $50 per radio each time the radio needed to be touched and estimated that each radio would need to be touched twice.[4] Motorola believes that this is a reasonable assumption for such work, although the actual costs could vary. While this cost would cover the time for a technician to actually handle a single radio and install new software, much of the expense will be in developing new software for each model radio and developing programming specific to each user situation to ensure correct operation. Software for each model radio

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[4] See *Supplemental Comments of the Consensus Parties*, WT Docket No. 02-55, December 24, 2002, at A-12.

will need to be done before rebanding begins and could total $20-25 million across all models. Per radio costs also do not cover the changes to infrastructure or base station radios.

IV. Testing for Interference

On July 17, 2003 Motorola met with the Chief, Office of Engineering and Technology and members of his staff and presented information on methods and results of testing for interference in the 800 MHz band.[5] Attachment A is provided in response to the staff's request for additional information on a test setup and procedure that would allow entities to readily determine the interference mechanism and help identify the actual interferer for a particular interference incidence. Motorola notes that information on testing methods has also been provided in the record of this proceeding by other parties.[6] It is likely that all of these testing methods will contribute to developing the most accurate, repeatable and reliable procedure that could be implemented with the least burden or impact on users. Motorola would be pleased to participate in industry discussions to finalize a complete approach to testing.

5 *See* Motorola, Inc. Ex Parte filing dated July 18, 2003 in WT Docket 02-55.

6 *See Ex Parte Submission by the Consensus Parties*, date August 7, 2003, at Section 5 of Attachment 1, *Enhanced Appendix F*, and the Nextel guide, *How to Respond to Reports of Interference*, Nextel Ex Parte filing dated October 22, 2003.

V. Conclusion

Motorola appreciates the opportunity to provide this information to the Commission. If you have questions or require additional information, please contact the undersigned.

Sincerely,

__/s/ Steve B Sharkey__________

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Attachment A

1 Introduction

This paper presents a representative testing configuration that may be used to determine the service level source of potential interference into public safety systems operating in the 800 MHz band. The description of this configuration provides additional information regarding testing information presented to Commission staff during a July 17, 2003 Ex Parte meeting. The test setup was designed to provide enough flexibility to consider a variety of test requirements along with minimizing the extent of manual configuration. The approach contained herein produces accurate and repeatable results in the majority of the situations under consideration but there will be some scenarios in which the issues discussed in section 4 could lead to further modifications of the proposed test setup in order to reduce measurement errors in the setup.

This method is not intended to identify the specific carrier frequencies responsible for interference to a public safety system but the service of which that carrier belongs. Information on testing methods and requirements has also been provided in the record of this proceeding by other parties.[7] It is likely that all of these testing methods will contribute to developing the most accurate, repeatable and reliable procedure that could be implemented with the least burden or impact on users. An industry group would provide the best means of finalizing the most effective and efficient methodology. Motorola would be pleased to participate in such a group.

The following interference cases exist that may produce interference into public safety systems:

Table A.1: Potential Sources of Service Level Interference.

Indicator	Source of interference
C_s	Specialized Mobile Radio Service (SMR)[8] systems
C_a	Cellular band A systems
C_b	Cellular band B systems
C_s+C_a	Mixing of signals from SMR and cellular band A systems
C_s+C_b	Mixing of signals from SMR and cellular band B systems
C_a+C_b	Mixing of signals from cellular band A and B systems
$C_s+C_a+C_b$	Mixing of signals from SMR, cellular band A and B systems

The associated channel allocation defined in Part 90 of the Commissions rules is depicted in Figure 1.

7 *See Ex Parte Submission by the Consensus Parties*, date August 7, 2003, at Section 5 of Attachment 1, *Enhanced Appendix F*, and the Nextel guide, *How to Respond to Reports of Interference*, Nextel Ex Parte filing dated October 22, 2003.

8 In the context of this discussion SMR includes all commercial operators in the SMR band allocated under part 90.617 of the Commissions rules.

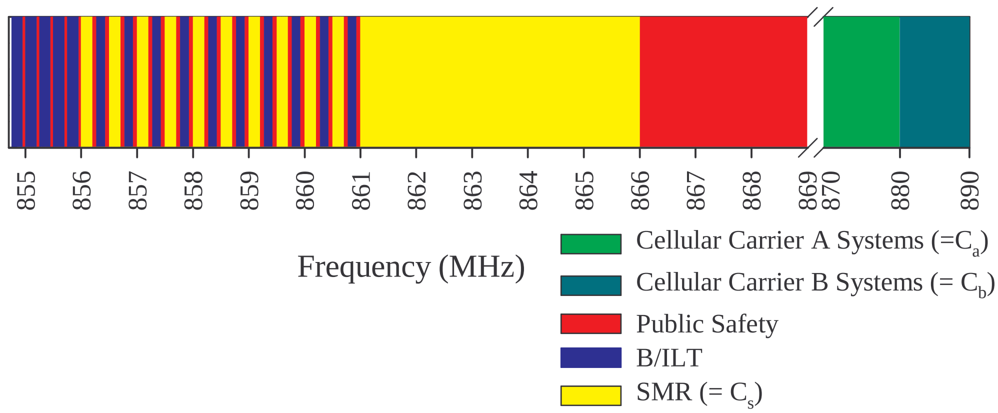

Figure 1: Channel Allocation.

2 Discussion

A single setup is presented which utilizes combinations of multiple filters installed in series to produce the desired test configuration. This flexible test configuration may be used to determine whether or not a particular band is involved in the production of interference to public safety radios.

2.1 Test Configuration and Method

A single test setup will provide enough flexibility to consider a variety of test requirements while minimizing the extent of manual configuration. The test configuration consisted of sets of filters that can be switched in or out of the signal path as shown in Figure 2. The following sets of filters with isolators may be installed to produce a wide notch that will attenuate the indicated band for a particular test scenario. [9]

Table A.2: Required Notch Filters

Filter Set	Notch band	Note
A	869-879 MHz	Cellular A band
B	880-890 MHz	Cellular B band
SMR	861-866 MHz	Specialized mobile radio systems band
Interleaved SMR	Specific bands between 851-861 MHz	Narrow notch for specific SMR frequencies that are interleaved with the Public Safety. This type of filter may have higher insertion loss than the above filters.

[9] The circulator used in the notch filter section should be a design known to have a high intercept point such that the likelihood of intermodulation generation in the notch filter section is minimized.

A possible filter configuration is shown in Figure 2, which employs a switching configuration. The configuration must be tested to ensure that the accumulation of switch contacts does not increase the total loss of the combination to the point that the intermodulation results are significantly impacted. An alternatively configured setup would require significantly more time for the test operator to manually disconnect and reconnect filters between each test.

Combinations of multiple filters can be installed in series to produce the desired configuration to determine whether or not a particular band is involved in the production of interference to public safety radios. The rest of the test setup contains a variable attenuator, a coupler, a signal source, a SINAD meter and device under test (receiver). The signal source and the SINAD meter may be provided within one service monitor in some commercial products.

Narrow notch filters are required to identify potential interferers that are located within the interleaved portion of the allocation. This type of narrowband filter may be difficult to adequately tune in typical field applications and should be considered optionally as part of an enhanced diagnostic tool. Multiple narrowband notch filters may be used in combinations to isolate multiple potential interleaved contributors. The insertion losses of the system will increase as more filters are cascaded, subsequently reducing the level of intermodulation products created in the victim receiver. For optimal test system effectiveness the insertion loss of the switchable filter bank should be minimized.

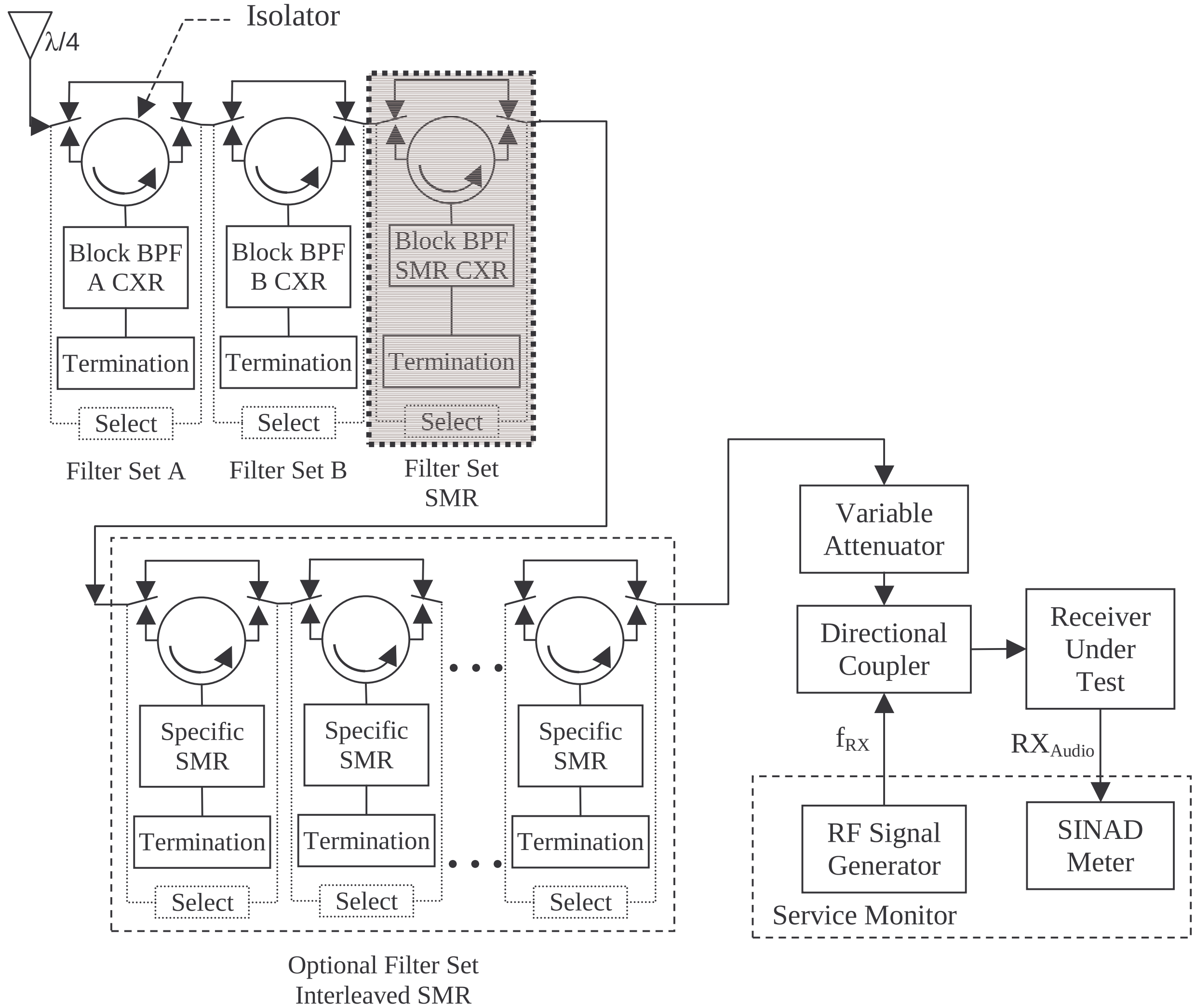

Figure 2: Test Schematic.

Representative characteristics of the SMR filter set outlined in the shaded box are shown in Figures 3 and 4. Figure 3 is the response of the bandpass filter and Figure 4 shows the notch filter response created when the circulator load port is terminated with the bandpass filter.

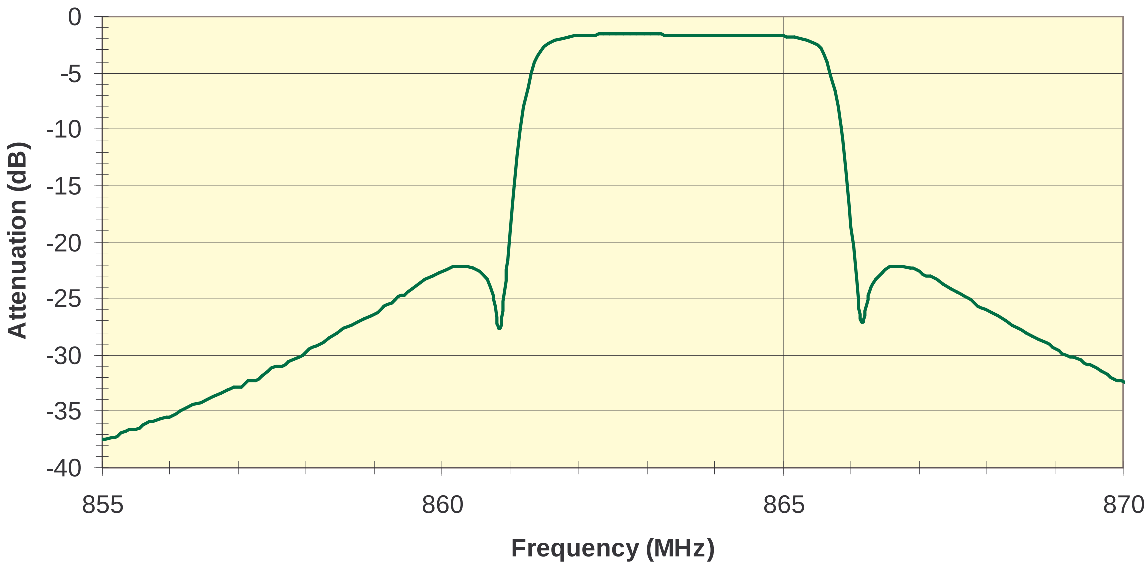

Figure 3: SMR Bandpass filter response.

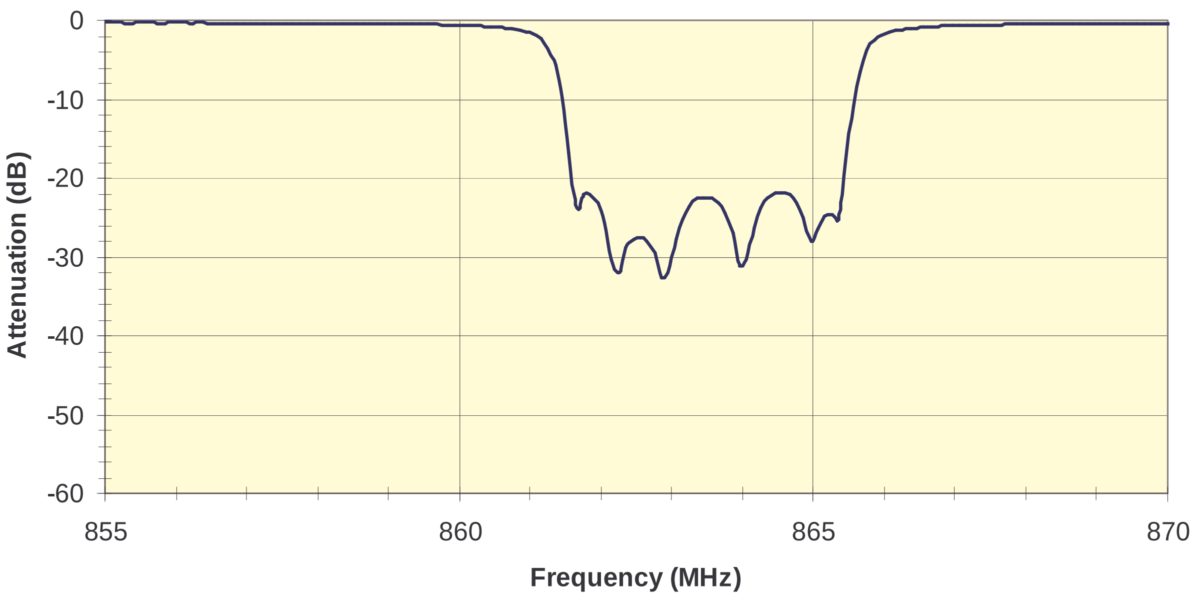

Figure 4: SMR Notch filter response.

2.2 Analyzing test results

Measurements are performed using combinations of multiple filters that determine whether or not a particular band is involved in the production of interference to public safety radios. For each measurement taken the results are fitted in a least square error method with lines of slope

1:1, 3:1 and 5:1. The line of slope 1:1 represents interference from out-of-band sources[10], the line of slope 3:1 represent interference from 3rd order intermodulation (IM) products generated in the receiving device and the line of slope 5:1 represent interference from 5th order IM generated in the receiving devices. A more detailed example of the measurement process and data analysis process are shown in section 3.

In order to identify the source of interference the following steps are suggested:

1) Perform the seven measurements corresponding to the filter sets lists in column one of Table A.3.[11]
2) For each measurement perform a least squares curve fit as described in section 3.1 to identify the type of interference present in the measurement.
3) For each line used in the least square curve fit a decision must be made if it is a significant contributor to the overall measured interference.[12]
4) The results of step 3 are used to determine the source of interference by comparison with Table A.3 for each type of interference (out-of-band, 3rd order IM and 5th order IM).[13]

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[10] In the event that intermodulation is produced at the transmitting antenna and/or tower, that signal would be on frequency of the measurement device and will be measured with a 1:1 slope.

[11] If the source of interference is to be identified as coming from a specific interleaved frequency, then the channel specific filter(s) are be required to be individually tested and recorded. This would increase the number of measurement sets and the extent of Table A.3 will need to be expanded. This is considered to be beyond the high level discussion of this document.

[12] One potential decision point could be if the removal of any particular line used in the curve fit would change the least square fit residual by 100% or more, then the line is considered a significant contributor to the measurement. Further investigation is warranted on this decision point.

[13] For example if the line of slope 1:1 would be a significant contributor to measurements performed with no filters, filter B, filter CMRS and filter B+CMRS and all other measurements do not have significant contributions, it can be concluded that the interference power present in public safety receiver is due to out-of band emissions from cellular band A operations.

Table A.3: Filter matrix to find interference source

Active Filter(s)[14]	**Source of interference**						
	C_s	C_a	C_b	$C+C_a$	$C+C_b$	C_a+C_b	$C+C_a+C_b$
None	Y	Y	Y	Y	Y	Y	Y
A	Y	N	Y	N	Y	N	N
B	Y	Y	N	Y	N	N	N
SMR	N	Y	Y	N	N	Y	N
A+B	Y	N	N	N	N	N	N
A+SMR	N	N	Y	N	N	N	N
B+SMR	N	Y	N	N	N	N	N

3 Example

As an example, consider the two sets of measurements; one where no filters are selected and another where notch filters for the Cellar A and B band are selected. The steps below outline the procedures used to perform the measurements, section 3.1 outline the steps for data analysis and section 3.2 presents the results for the two different sets of measurements. Procedure for measurements:

1. Determine a candidate frequency in the victim system and remove that frequency from service.
2. Connect equipment per Figure 2 with no filters selected.
3. Set variable attenuator to max value (>80 dB) or terminate the input of the directional coupler with a 50 ohm load.
4. Adjust the RF signal generator frequency to the receiver frequency.
5. Modulate the RF signal generator with a standard input signal for the system type under evaluation.
6. Adjust RF signal generator output level to establish system sensitivity criterion, e.g., 12 dB SINAD. Record the signal generator output level as $P_{Desired}$ (dBm).
7. Measure the insertion loss (IL) from the output of the RF signal generator to the receiver input port. Record as IL in dB.
8. Calculate the receiver sensitivity, Ps
   $$Ps = P_{Desired} - IL \quad (dBm)$$
9. Adjust the variable attenuator for 0 dB.
10. Adjust the RF signal generator output level to re-establish the sensitivity criterion (12 dB SINAD) and record $P_{Desired}$.
11. Repeat steps 9 and 10 for each attenuator setting (e.g. Steps of 1-2 dB).

[14] The A+B+CMRS filter combinations are not required to be measured since this measurement conveys no information. All filters are band pass filters for their entire band with the exception of the channel specific filter used for in band interference identification.

12. Repeat steps 3 thru 11 for various combinations of filters based on the initial data analysis in the following section.

3.1 Data Analysis

1. Plot the measured data, $P_{Desired}$ vs. attenuator value.
2. Generate a curve fit using a model based on the following components:
    a) Receiver noise floor (m=0)
    b) OOBE[15] (m=1, 1:1 slope)
    c) 3rd order IM (m=3, 3:1 slope)
    d) 5th order IM (m=5, 5:1 slope)
    e) Carrier to noise ratio to establish sensitivity criterion (C/N, dB)

$$P_{Desired} = RX_n + OOBE + IM3 + IM5 + C/N$$

Each of the components of the model is of the form y = mx + b.

The receiver noise floor (RX_n) is determined by subtracting the C/N from the $P_{Desired}$ measured for the attenuator set to the maximum value.

The slope of each remaining component (m) is as indicated above. For each component of the model where $m \geq 1$, it is necessary to determine the y intercept of the line for m = 1, 3 & 5. Data analysis tools can be used to minimize the differences of the squares of the measured data and model results.

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The optimized model provides an estimate of each type of interference to assist in further decomposition of the signal sources that cause the interference.

3.2 Results

Two sets of measurements are shown in Figure 5. The figure on the left displays the results for when no notch filters are active, the figure on the right displays the results when notch filters A and B are active. The line with slope of 1:1 clearly indicates that out-of-band interference is present in both sets of measurement. Therefore it can be concluded that interference present is due to out-of-band interference from a SMR system or external IM from an unknown source.[16] The remaining interference from 3rd order IM (line of slope 3:1) and 5th order IM (line of slope 5:1) that is shown with the measurements from no active filters indicates that additional measurements are needed to determine the specific band that is the IM interference source.

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15 For the purpose of this document, OOBE contains all energy outside of the desired channels bandwidth. This would include the ITU definitions for OOBE and the spurious domain.

16 External IM is an IM signal generated from another source, external to the receiver under test. Typical examples of external IM include transmitter generated IM, IM generated in a faulty transmission line connector or IM generated within a rusty tower junction.

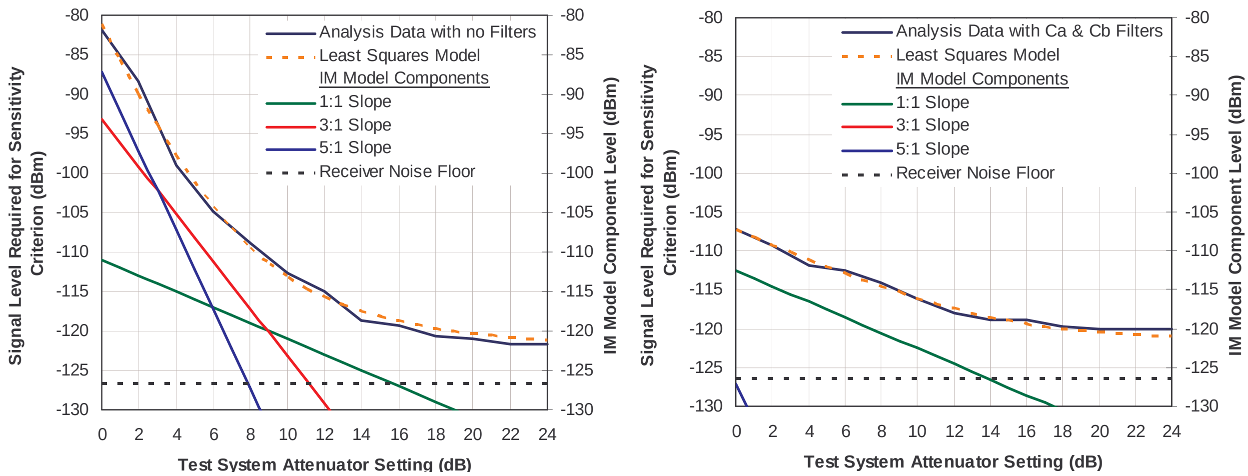

Figure 5: Measurement results with and without A+B notch filters present.

4 Areas for further consideration

The test configuration may need to be modified in some cases. Issues that can impact the test configuration are listed below:

- Spectrum allocations will vary by market so the test configuration may need to be modified for each market.
- If it is desired to specifically identify interleaved channels that contribute to intermodulation product(s), then individual channel-specific filters must be incorporated into the test configuration and the corresponding table to that found in Table A.3 will grow exponentially.
- The recommended configuration maximizes flexibility and automation via the use of switchable filters. Complications of this flexibility are:
  - The insertion loss will increase as more filter/relay bands are cascaded and the level of intermodulation products created in the victim receiver will be reduced correspondingly. The insertion loss of switchable filters should be minimized for optimal effectiveness.
  - A manually configured setup may be required if a switched setup becomes too lossy. A manually configured setup will be time consuming and will be difficult to operate in an automated measurement process.
- The narrowband filters used to remove the interleaved sources of intermodulation may be difficult to adequately tune in typical field applications.